



**TECHNICAL REPORT
NATICK/TR-99/009**

AD _____

DEVELOPMENT OF RADAPPERTIZED PORK ITEMS

by
**Gary W. Shults
Joseph S. Cohen
John J. Howker
and
Eugen Wierbicki**

November 1998

Final Report
August 1970

19981124 018

Approved for Public Release; Distribution Unlimited

**U.S. ARMY SOLDIER AND BIOLOGICAL CHEMICAL COMMAND
SOLDIER SYSTEMS CENTER
NATICK, MASSACHUSETTS 01760-5018**

DISCLAIMERS

The findings contained in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

DESTRUCTION NOTICE

For Classified Documents:

Follow the procedures in DoD 5200.22-M, Industrial Security Manual, Section II-19 or DoD 5200.1-R, Information Security Program Regulation, Chapter IX.

For Unclassified/Limited Distribution Documents:

Destroy by any method that prevents disclosure of contents or reconstruction of the document.

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE November 1998	3. REPORT TYPE AND DATES COVERED FINAL August 1976		
4. TITLE AND SUBTITLE DEVELOPMENT OF RADAPPERTIZED PORK ITEMS		5. FUNDING NUMBERS C 8AB81A N 3122		
6. AUTHOR(S) Gary W. Shults, John J. Howker, Joseph S. Cohen and Eugen Wierbicki				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Soldier and Biological Chemical Command Soldier Systems Center ATTN: SBCCOM-W Natick, MA 01760-5018		8. PERFORMING ORGANIZATION REPORT NUMBER NATICK/TR-99/009		
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSORING / MONITORING AGENCY REPORT NUMBER		
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited		12b. DISTRIBUTION CODE		
13. ABSTRACT (Maximum 200 words) This report describes the production of irradiation sterilized (radappertized) pork rolls and chops. Extensive sensory and preference studies were conducted on the finished product. The optimum balance of quality and prevention of loss of natural juices during enzyme inactivation was obtained using 0.3% Na-TPP and 0.75 to 1.0% sodium chloride (NaCl). The cooking loss was reduced with the use of the additives with a corresponding increase in preference scores of the irradiated products. The increase in the preference scores was attributed to improved flavor and texture.				
14. SUBJECT TERMS RADAPPERTIZED MEATS IRRADIATION SHELF STABLE MEALS STORAGE STABILITY SENSORY ANALYSIS RADIATION STERILIZATION STORAGE TIME PORK			15. NUMBER OF PAGES 27	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT SAR	

TABLE OF CONTENTS

List of Tables	vii
Preface	ix
Introduction	1

LIST OF TABLES

	<u>Page No.</u>
1. Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Radappertized Pork Chops	2
2. Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Chops	2
3. Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Chops	3
4. Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Chops	3
5. Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Rolls	3
6. Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Radappertized Pork Rolls	4
7. Effect of TPP and Pepper on the Sensory Characteristics of Non-Irradiated Pork Rolls	4
8. Effect of Irradiation Temperature and Dose on the Sensory Characteristics of Radappertized Pork Loins	5
9. Effect of Irradiation Temperature on the Sensory Characteristics of Characteristics of Radappertized Pork Loins	6
10. Consumer Panel Ratings of Pork Chops	7
11. Yield Data of Pork Chops and Rolls	7
12. Effect of NaCl and TPP on the Organic Volatiles of Pork Chops	8
13. Effect of NaCl and TPP on the Shear Press Values of Pork Chops	8
14. Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Chops	8
15. Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Rolls	9
16. Effect of NaCl and TPP on the Sensory Characteristics of Pork Rolls	9
17. Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Rolls	10
18. Effect of NaCl and TPP on the Shear Values of Pork Rolls	10
19. Effect of NaCl and TPP on the Organic Volatiles of Pork Rolls	10
20. Effect of NaCl on the Sensory Characteristics of Non-Irradiated Pork Rolls	11
21. Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Rolls	11
22. Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Rolls	12
23. Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Rolls	12

24. Effect of NaCl and TPP on the Consumer Evaluation of Non-Irradiated Pork Rolls	13
25. Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Pork Rolls	14
26. Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Chops	15
27. Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Chops	16
28. Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Pork Products	17
29. Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Pork Products	18

PREFACE

The data for this report were collected by investigators from the US Army, Natick Research and Development Command during the 1970s.

It is being published now as the Army has expressed a need for irradiation sterilized meat products. The data is relevant.

Shelf stable pork items of uniform density and geometric configuration, preserved by radappertization (radiation sterilization) have been developed.

Pieces of defatted raw pork were mixed with 0.3 or 0.5% Sodium Tripolyphosphate (Na-TPP) and 0.25, 0.50, 0.75 or 1.0% NaCl, stuffed into fibrous casings and enzyme inactivated in a smoke house to an internal temperature of 70 to 75 °C. After cooling, the pork rolls were cut to the desired length, resulting in uniform pieces (which permitted the optimum use of the space in a can), vacuum canned, frozen to -40 °C and irradiated with a sterilizing dose of 51 to 66 kGy while frozen at -30 ± 10 °C.

After irradiation the product was defrosted and kept at 21 to 30 °C prior to evaluation by an expert, technical panel for color, odor, flavor, texture and by a consumer panel for preference. An optimum balance of quality and prevention of loss of natural juices during enzyme inactivation was obtained by using 0.3% Na-TPP and 0.75 to 1.0% sodium chloride (NaCl). The cooking loss was reduced from 29% without additives to 16% with additives. There was a corresponding increase in preference scores for the irradiated item from a range of 4.3 - 6.3 to 5.2 - 7.2 on the 9 point hedonic scale. The increase in the preference scores is attributed to improved flavor and texture (sensory and Kramer shear press data).

High quality, shelf-stable radappertized pork chops were prepared by Injecto-pumping of pork loins to a yield of 0.3% Na-TPP and 0.75% NaCl. This was followed by oven broiling at 232 °C of 1.2 cm loin slices (pork chops) to an internal temperature of 70 to 75 °C. The cooked pork chops were vacuum packaged and then radappertized at -30 °C to a dose of 51 to 66 kGy. This produced excellent, shelf-stable radappertized pork chops. The chops received preference scores in the range of 6 to 7 from the expert and consumer-type panels. Storage stability studies of the products were initiated.

Irradiation was done with the Co⁶⁰ source of gamma particles.

The scale used ranged from 1-dislike extremely to 9-like extremely with 5-neither like nor dislike.

DEVELOPMENT OF RADAPPERTIZED PORK ITEMS

Introduction

Investigations on cured meat products have been directed toward reducing the amounts of sodium nitrate and sodium nitrite required for the production of these products. These efforts have been motivated by the acknowledgement that nitrosamine formation in cured meats is directly associated with the addition of curing salts. Research was conducted on the development of cured meats with the minimal amount of curing salts to determine which additive level produces a product with the characteristic color and microbiological safety. The US Department of Agriculture's (USDA) 1973 regulations eliminated the use of sodium nitrate (NaNO_3) as a curing ingredients in meats except for dry cured ham and fermented sausage. The approved level of sodium nitrite (NaNO_2) addition was also substantially lowered.

Weirbicki and Heiligman (1973) reported extensive investigations on the reduction of NaNO_3 and NaNO_2 in irradiated ham. They reported that the additive level of NaNO_2 could be reduced to 25 ppm when used in combination with 100 ppm of NaNO_3 . Without the 100 ppm of NaNO_3 , fading of the cured meat was detected and preference scores were lowered. Wasserman (1978) reported that no nitrosamines were found in irradiated cured meats when lower levels of NaNO_2 and NaNO_3 were used. Wierbicki et al. (1974) reported that the level of NaNO_2 addition could be reduced from 156 to 75 ppm in nonirradiated cured meats without affecting the quality. Wierbicki et al. (1976) reported that acceptable irradiated corned beef can be produced with an addition of 156 ppm NaNO_2 without NaNO_3 . Shults et al. (1977) also showed that an addition level of 150 ppm NaNO_2 was sufficient to produce acceptable irradiated corned beef. An addition level of 25 ppm NaNO_2 also produced an acceptable product, but with decreased color intensity. Cohen et al. (1978) reported that an acceptable irradiated corned beef could be produced with the addition of 75 ppm NaNO_2 without the NaNO_3 addition.

This study was initiated to investigate the effects of low level additions of NaNO_2 and NaNO_3 on the color, acceptance and nitrosamine formation in irradiated and nonirradiated corned beef.

Materials and Methods

The raw material used for these studies was fresh beef brisket, pectoralis profundis muscle, excised from USDA choice grade carcasses. The briskets were trimmed of all surface fat and injecto-pumped with a Griffith #8 Big Boy™ meat pump (The Griffith Laboratories, Inc., Chicago, IL) operating at 90 Pa of pressure. The briskets were pumped to 15% added weight with the curing solutions. Each cure contained 3.0% sodium chloride, 275 ppm sodium ascorbate and 275 ppm sodium erythorbate. NaNO_2 levels evaluated were 150, 75, 3.5, 25 and 0 ppm. NaNO_3 levels were 50, 37.5, 25 and 0 ppm. Various combinations were used. The briskets were held for 72 hours at $+2^\circ\text{C}$ after pumping, prior to cooking.

The cured briskets were cooked in a water kettle at $97 \pm 1^\circ\text{C}$ until an internal temperature of $80 \pm 2^\circ\text{C}$ was attained and then simmered at 75°C for one hour. After cooking the briskets were cooled at 2 to 5°C .

Table 1 - Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Radappertized Pork Chops

NaCl	TPP	Dose	Sensory Characteristics									
			Color		Odor		Flavor		Texture		Preference	
			Days Storage									
			0	30	0	30	0	30	0	30	0	30
%	%	kGy	0	30	0	30	0	30	0	30	0	30
0.00	0.00	51	5.7**	6.7	4.9	7.1	4.8	5.7**	5.4**	5.5**	5.1	5.8**
0.75	0.00	51	6.1	6.7	5.9	6.6	5.4	6.1	6.4	6.3	5.6**	6.2
0.75	0.25	51	5.6**	6.9	6.4*	7.0	5.4	5.8**	5.8	6.5	6.3*	6.1
0.75	0.50	51	6.6	7.3	6.4*	6.9	5.5	6.7	6.1	6.5	6.3*	6.5
0.75	0.25	NA	6.9	7.5	6.4*	7.7	5.8***	7.6	6.1*	7.3	7.1	7.3

* Significantly different from the sample with no additives

** Significantly different from the non-irradiated sample

*** Significantly different from the other samples.

Significance determined for 0.05 level

10 Panelists per test, 9-point scale

- The non-irradiated sample was preferred over all the irradiated. The scores also increased with storage. The irradiated sample with the greatest NaCl and TPP was preferred over the others.

Table 2 - Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Radappertized Pork Chops

NaCl	TPP	Days Storage											
		0		30		0		30		0		30	
		Sensory Characteristic										Preference	
		Color		Odor		Flavor		Texture					
%	%												
0.00	0.00	6.1	7.4	5.2	6.4**	4.4	6.2	6.0	6.5	5.0	6.4		
0.75	0.00	6.3	6.6	5.3	7.2	4.5	6.4	6.1	6.0	5.1	6.2		
0.75	0.30	6.5	7.5	6.9*	7.2	6.0*	6.8	6.6	7.3	6.5*	6.8		
0.75	0.50	6.2	7.2	6.0	7.2	6.1*	6.8	6.2	6.9	6.2*	6.7		

* Significantly different from the samples with no additives and 0.75% NaCl 0.05 level

** Significantly different from the other samples at 0.05 level

10 panelists per test, 9-point scale

Irradiation Conditions: 51 kGy at $-25 \pm 20^{\circ}\text{C}$

- The samples with TPP were preferred. There was no preference for the amount of TPP. The scores increased with storage time.

Table 3 - Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Chops

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Dose</u> <u>kGy</u>	<u>Sensory Characteristics</u>				<u>Preference</u>
			<u>Color</u>	<u>Odor</u>	<u>Flavor</u>	<u>Texture</u>	
0.75	0.30	51	7.5	6.7	5.9	6.1	6.4
0.75	0.00	51	6.9	6.6	5.6	6.2	6.2
0.75	0.30	NA	7.0	6.2	6.2	6.2	6.1
0.75	0.00	NA	7.5	6.9	6.9	7.1	7.0

12 panelists per test. 9-point scale Irradiation Conditions: 30 ± 10 °C

- The additives had no effect. The non-irradiated sample was preferred over all the irradiated samples.

Table 4 - Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Chops

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Sensory Characteristic</u>				
		<u>Color</u>	<u>Odor</u>	<u>Flavor</u>	<u>Texture</u>	<u>Appearance</u>
0.00	0.00	7.1	6.1	5.5	6.5	5.9
0.25	0.30	7.2	6.7	6.5	6.5	6.4
0.50	0.30	7.4	7.4	7.5	6.5	7.2
0.75	0.30	7.1	6.2	6.6	6.5	6.6
0.50	0.00	6.9	6.5	6.5	6.0	6.6

12 panelists per test, 9-point scale

- The sample with 0.5% NaCl and 0.3% TPP was preferred.

Table 5 - Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Rolls

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Dose</u> <u>kGy</u>	<u>Sensory Characteristics</u>				<u>Preference</u>
			<u>Color</u>	<u>Odor</u>	<u>Flavor</u>	<u>Texture</u>	
0.00	0.0	51	6.2	5.1	4.7	5.6	5.7
0.25	0.3	51	6.7	6.2	5.7	6.9	5.9
0.50	0.3	51	6.4	6.2	5.7	6.6	6.2
0.75	0.3	51	6.1	5.9	6.0	6.2	5.9
0.50	0.0	51	6.1	5.0	5.2	6.1	5.2

12 panelists per test, 9-point scale

- The sample with 0.5% NaCl and no TPP rated lower than the others. There was no preference for the % of NaCl.

Table 6 - Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Radappertized Pork Rolls

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Irrad.</u> <u>Dose</u> <u>kGy</u>	<u>Days Storage</u>									
			<u>30</u>	<u>90</u>	<u>30</u>	<u>90</u>	<u>30</u>	<u>90</u>	<u>30</u>	<u>90</u>	<u>30</u>	<u>90</u>
			<u>Sensory Characteristic</u>									
			<u>Color</u>		<u>Odor</u>		<u>Flavor</u>		<u>Texture</u>		<u>Preference</u>	
0.75	0.3	51	6.0	6.6	5.7	6.4	5.2	6.1	6.1	6.1	5.5	5.9
0.75	0.0	51	6.0	6.0	5.4	5.7	4.7	5.0	5.4	4.7	5.2	5.4
0.75	0.3	NA	6.5	7.5	7.0	7.5	7.0	7.4	7.0	7.1	6.8	7.1
0.75	0.0	NA	6.9	6.6	6.7	6.9	6.6	7.0	7.1	6.7	6.5	6.1

12 panelists per test, 9-point scale

Irradiation temperature: $-30 \pm 10^{\circ}\text{C}$

- The unirradiated samples were preferred over the irradiated. The samples with TPP were preferred over the samples without. The scores tended to increase with storage.

Table 7 - Effect of TPP and Pepper on the Sensory Characteristics of Non-Irradiated Pork Rolls

<u>Addition</u> <u>TPP</u> <u>Pepper</u> <u>%</u> <u>%</u>		<u>Test Number</u>											
		<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>
		<u>Sensory Characteristic</u>											
		<u>Color</u>			<u>Odor</u>			<u>Flavor</u>			<u>Texture</u>		
0.0	0.0	7.2	6.9	5.8	7.0	7.1	5.7	7.1	6.7	5.2	7.2	6.8	5.6
	Mean	6.3			6.6			6.3			6.5		
0.3	0.0	6.3	6.7	5.9	6.8	7.0	5.4	6.5	6.8	4.9	6.8	6.7	5.0
	Mean	6.3			6.4			6.1			6.2		
0.3	0.1	6.9	6.6	5.5	7.1	6.9	5.8	7.0	6.6	5.0	7.0	6.9	5.5
	Mean	6.3			6.6			6.2			6.5		

12 panelists per individual test, 9-point scale

All samples contain 0.75% NaCl

Irradiation Conditions For All Samples: dose 51 kGy at $-30 \pm 10^{\circ}\text{C}$

1 month storage

- There was no preference for TPP or pepper addition.

Table 8 - Effect of Irradiation Temperature and Dose on the Sensory Characteristics of Radappertized Pork Loins

<u>Irradiation Conditions</u>			<u>Sensory Characteristics</u>					
<u>Dose</u>	<u>Temp.</u>	<u>Storage</u>				<u>Irrad.</u>	<u>Off-</u>	
<u>kGy</u>	<u>°C</u>	<u>days</u>	<u>Discolor</u>	<u>Off-Odor</u>	<u>Mushiness</u>	<u>Flavor</u>	<u>Flavor</u>	<u>Preference</u>
35	0	0	2.6	2.0	3.8	2.0	2.0	5.4
35	0	30	2.3	1.8	2.0	2.6	1.3	5.8
35	0	90	3.2	1.7	1.8	2.8	2.0	5.2
35	-80	0	2.1	1.9	2.1	1.5	2.4	6.0
35	-80	30	2.9	2.3	2.6	3.4	1.1	5.8
35	-80	90	2.3	1.8	1.7	2.3	1.5	5.0
45	0	0	2.1	2.6	2.5	3.1	1.9	5.4
45	0	30	2.5	1.9	1.4	3.1	1.4	5.1
45	0	90	2.3	2.2	1.8	2.7	1.8	5.3
45	-80	0	2.3	2.9	2.5	2.6	1.9	5.4
45	-80	30	3.5	2.6	2.8	3.0	1.1	5.8
45	-80	90	2.2	2.7	2.5	2.8	1.8	5.3
NA*	NA*	0	1.0	1.0	1.6	1.0	1.0	7.3
NA*	NA*	30	1.4	1.5	2.4	1.5	1.4	6.9
NA*	NA*	90	1.2	1.3	1.7	1.3	1.3	6.4

8 panelists per test

* Frozen Control

Preference ratings used a 9-point scale.

Sensory Characteristics used a reverse 7-point scale that ranged from 1 -none detected to 7-extreme

- There was a lowering of preference scores between 30 and 90 days of storage. There was no preference for irradiation dose or temperature. All the irradiated samples were rated lower than the irradiated one.

Table 9 - Effect of Irradiation Temperature on the Sensory Characteristics of Radappertized Pork Loins

<u>Irrad.</u> <u>Temp.</u> <u>°C</u>	<u>Storage</u> <u>Time, days</u>	<u>Sensory Characteristics</u>					<u>Preference</u>
		<u>Discolor-</u> <u>ation</u>	<u>Off-</u> <u>Odor</u>	<u>Mushi-</u> <u>ness</u>	<u>Irrad.</u> <u>Flavor</u>	<u>Off-</u> <u>Flavor</u>	
0	0	3.9	2.4	2.1	2.6	2.0	4.8
0	30	2.0	2.9	1.5	2.8	1.9	4.9
0	90	3.5	2.8	3.0	3.2	1.8	4.9
-80	0	2.1	1.8	1.1	2.4	2.1	5.5
-80	30	3.0	2.6	1.9	2.1	1.1	6.4
-80	90	2.8	2.3	2.3	3.2	1.7	4.3
-185	0	1.4	1.3	1.0	1.4	1.6	6.9
-185	30	1.9	2.5	2.5	1.6	1.1	6.8
-185	90	2.8	2.8	3.2	2.3	1.7	5.0
NA	0	1.0	1.3	1.0	1.1	1.5	7.1
NA	30	2.0	1.6	2.1	1.5	1.5	6.9
NA	90	2.3	1.5	2.5	1.0	2.2	6.4

8 panelists per test

45 to 56 kGy irradiation dose

Preference Ratings used a 9-point scale

Sensory Characteristics used a reverse 7-point scale that ranged from
1-none detected to 7-extreme

- There was a decreased preference after 30 days of storage.
There was an increased preference with decreased irradiation temperature.
The lowest irradiation temperature initially rated very close to the sample that was not irradiated.

Table 10 - Consumer Panel Ratings of Radappertized Pork Chops

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Preference Rating</u>	
		<u>Irradiated</u>	<u>Non-Irradiated</u>
0.00	0.00	5.3	5.8
0.75	0.00	5.9	6.8*
0.75	0.25	6.4*	6.6*
0.75	0.50	6.4*	6.5*

* significantly different from the sample with no NaCl and TPP

32 - 35 panelists per test, 9-point scale

All significance at 0.05 level

- All the samples with NaCl or TPP addition were preferred.
The non-irradiated samples were preferred, over the irradiated, although the samples with additives rated only slightly better.

Table 11 - Yield Data of Pork Chops and Rolls

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>% Cooking Loss</u>	
		<u>Pork Chops*</u>	<u>Pork Rolls**</u>
0.00	0.00	34	29
0.75	0.00	32	21
0.75	0.25	26	16
0.75	0.50	25	15

* Average of 42 lb (19 kg) of pork chops per sample
Each chop cut into 0.5 in (1.3 cm) thickness

** Average of eight samples

Enzyme inactivated in broiler to 71 - 75 °C internal temperature

- The addition of TPP decreased the cooking loss.

Table 12 - Effect of NaCl and TPP on the Organic Volatiles of Pork Chops

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Non-Irradiated</u>		<u>Irradiated</u>			
		<u>pH</u>	<u>ORV*</u>	<u>Days Storage</u>			
				<u>pH</u>		<u>ORV</u>	
				<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>
0.00	0.0	5.8	0.87	5.5	5.5	1.1	1.1
0.75	0.0	5.8	1.21	5.7	5.7	0.9	1.3
0.75	0.3	5.9	0.65	5.9	6.0	1.2	1.3
0.75	0.5	6.0	1.15	6.3	5.9	1.5	1.3

* Organic Reducing Volatiles milliequivalents oxygen per 100 g meat

Irradiation Conditions: 51 kGy dose at -30 °C

- The addition of additives increased the pH of the irradiated samples. The ORV changes are not significant.

Table 13 - Effect of NaCl and TPP on the Shear Press Values of Pork Chops

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Shear Value (N)</u>	
		<u>Irradiated</u>	<u>Non-irradiated</u>
0.00	0.00	49.8 b,d	58.0 c,f
0.75	0.00	42.3 b,d	46.0 c,f
0.75	0.25	30.5 e	37.7 g
0.75	0.50	36.9 a,e	36.5 a, g

samples followed by the same letter are not significantly different. 0.05 level

- Irradiation decreased the shear value (the product became softer). The addition of NaCl also decreased the shear value, as did the addition of TPP

Table 14 - Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Chops

NaCl	TPP	Storage Time, Days											
		0		30		0		30		0		30	
		Sensory Characteristic											
%	%	Color		Odor		Flavor		Texture		Preference			
0.00	0.00	7.2	7.4	6.4	7.0	6.4	6.9	5.6	6.3	5.9	6.9		
0.75	0.00	7.3	7.4	7.0	7.0	7.0	7.4	6.9	6.4	6.9	7.0		
0.75	0.30	7.4	7.0	7.4	6.4	7.2	6.7	7.3*	6.6	7.1*	6.9		
0.75	0.50	7.5	7.4	7.3	7.1	7.3	7.3	7.3*	6.5	7.0*	7.2		

* significantly different from the sample with no NaCl and TPP
0.05 significance level

12 panelists per test, 9-point scale

- Addition of NaCl increased the scores. Addition of TPP did not.

Table 15 - Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Rolls

NaCl	TPP	Storage Time, Days											
		0		30		0		30		0		30	
		Sensory Characteristic											
%	%	Color		Odor		Flavor		Texture		Preference			
A. no storage													
0.00	0.00	6.2	6.1	6.2	6.2	5.2*	6.2*	5.0	6.0	5.5	5.9		
0.75	0.00	6.0	6.3	5.8	5.7	5.8	6.2	6.2	5.8	5.5	5.8		
0.75	0.25	5.5	6.0	5.8	6.2	5.5	6.2	5.9	5.6	5.5	6.0		
0.75	0.50	5.7	6.1	5.9	6.3	5.4	6.0	5.6	6.4	6.0	6.0		

10 - 12 panelists per test, 9-point scale

51 kGy irradiation dose at -30 °C

* significantly different at 0.05 level. No other significant differences.

- There was no effect if additive addition.

Table 16 - Effect of NaCl and TPP on the Sensory Characteristics of Pork Rolls

<u>Addition</u> <u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Irrad.</u> <u>Dose</u> <u>kGy</u>	<u>Storage Time, Days</u>									
			<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>
			<u>Sensory Characteristics</u>									
			<u>Color</u>		<u>Odor</u>		<u>Flavor</u>		<u>Texture</u>		<u>Preference</u>	
0.00	0.0	51	5.7	5.9	5.6**	4.8**	5.2	5.5	5.4	5.0**	5.6	5.2**
0.75	0.0	51	5.9	5.7	5.2**	5.4**	5.4	5.6	5.7	5.3**	5.3	5.7**
0.75	0.3	51	4.7	6.3	4.8**	6.1***	4.7	5.9	5.2	6.1	5.2	6.1***
0.75	0.5	51	5.8	6.2	7.0*	6.5***	6.7	6.1	7.1*	5.7	7.4*	6.2**
0.75	0.3	NA	7.0*	6.5	6.7	6.9	7.1*	6.8	7.0*	6.8	7.4*	7.2

10 - 12 panelists per test, 9-point scale

* significantly different from other samples

** significantly different from the non-irradiated sample

*** significantly different from the sample with no NaCl and TPP

Significance level - 0.05

- There was an effect of additive addition only after 30 days of storage.

Table 17 - Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Rolls

Addition		Storage Time, Days									
		0		30		0		30		0	
NaCl	TPP	Sensory Characteristics									
%	%	Color		Odor		Flavor		Texture		Preference	
0.00	0.00	6.0	7.1	5.9	6.7	5.7	5.6	5.2	6.1	5.9	6.1
0.75	0.00	6.0	6.9	5.7	7.0	5.9	6.9	6.4*	6.9	6.1	6.9
0.75	0.25	5.7	6.9	6.0	7.0	6.2	6.7	6.5*	7.7	6.2	6.5
0.75	0.50	5.7	6.5	5.8	6.7	6.2	7.1*	5.7	6.9	6.0	6.7

8 - 12 panelists per test, 9-point scale

* significantly different from the sample with no NaCl and TPP

- There were differences in storage time for color between the samples with no addition and the one with 0.25% TPP, at the 0.05 level

The addition of additives had no effect on the scores, as did the storage time.

Table 18 -Effect of NaCl and TPP on the Shear Values of Pork Rolls

NaCl	TPP	Shear Values, N	
		Irradiated	Non-Irradiated
%	%		
0.00	0.00	61.3 c	65.1 c
0.75	0.00	43.4	65.4 c
0.75	0.25	32.6 a,b	46.5 d,e
0.75	0.50	32.1 a,b	47.6 d,e

Samples followed by the same letter are not significantly different, 0.05 level

- Irradiation gave decreased shear values. The addition of either salt or TPP also decreased the shear values.

Table 19 - Effect of NaCl and TPP on the Organic Volatiles of Pork Rolls

NaCl	TPP	Non-Irradiated		Irradiated, no storage		Irradiated, 30 days storage	
		pH	ORV*	pH	ORV*	pH	ORV*
%	%						
0.00	0.0	6.2	1.1	6.4	1.2	6.1	1.9
0.75	0.0	5.9	1.1	6.0	1.1	5.9	1.2
0.75	0.3	6.1	1.1	6.3	1.2	6.2	1.2
0.75	0.5	6.4	0.9	6.7	1.23	6.4	1.8

Irradiation dose, 5.1 kGy at -30 °C

* Organic reducing volatiles, milliequivalents oxygen per 100 g meat

- There was no effect of additives on pH or ORV

Table 20 - Effect of NaCl on the Sensory Characteristics of Non-Irradiated Pork Rolls

<u>NaCl</u> <u>%</u>	<u>Sensory Characteristics</u>														
	<u>Off-Odor</u>			<u>Salty</u>			<u>Flavor</u>			<u>Off Flavor</u>			<u>Mushiness</u>		
	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>
0.0	1.8	2.2	1.3	1.0	1.5	1.3	1.5	2.0	2.2	1.5	2.0	1.0	1.1	2.0	1.5
Average	1.8			1.3			1.9			1.5			1.5		
1.0	1.8	2.1	1.3	1.1	1.1	1.8	1.8	2.1	2.3	1.1	2.1	1.0	1.0	2.0	1.5
Average	1.7			1.3			2.1			1.4			1.5		
1.5	1.5	1.8	1.5	1.3	1.0	1.5	2.3	1.8	2.0	2.2	2.0	1.0	2.0	1.8	1.8
Average	1.6			1.3			2.0			1.7			1.9		

Results of 3 tests in a 1 month storage period

7 to 8 panelists per test

9-point scale for preference, 7-point reverse scale for sensory characteristics

- There was no effect of NaCl addition on the sensory characteristics.

Table 21- Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Rolls

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Sensory Characteristics</u>					<u>Preference</u>
		<u>Off-Odor</u>	<u>Salty</u>	<u>Flavor</u>	<u>Off Flavor</u>	<u>Mushiness</u>	
0.5	0.5	1.1	1.3		1.3	1.1	6.1
1.0	0.5	1.3	1.5		1.3	1.6	6.7*
1.5	0.5	1.2	1.4		1.3	1.3	5.9
0.0	0.0	1.3	1.3		1.2	1.2	5.9

* significantly different from the 0 and 1.5% NaCl samples

18 panelists

9-point scale for preference, 7-point reverse scale for sensory characteristics

- The preferred sample was the one with 1% NaCl and 0.5% TPP addition.

Table 22 - Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Rolls

Dose kGy	NaCl %	Sensory Characteristics								Preference
		TPP %	Dis- Color	Off- Odor	Irrad. Flavor	Off- Flavor	Mushi- ness	Fria- bility		
NA	0.0	0.0	1.6	1.5	1.0 ***	1.5	1.1 ***	1.2 ***	6.5	
51	0.0	0.0	2.1	2.0 *	2.5	1.8	1.8	2.9	5.2 *	
51	0.5	0.5	2.6 *	2.0	1.4 **	1.4	2.4	2.6	5.5 *	
51	1.0	0.5	2.7 *	2.0	1.5 **	1.4	2.1	2.4	5.8 ***	
51	1.5	0.5	2.3	1.8	2.2	1.3	2.4	2.5	6.0	

* significantly different from the control samples

** significantly different from 2 and 5

*** significantly different from all other samples

**** significantly different from 2

23 panelists, 9-point scale for preference,

7 -point reverse scale for sensory characteristics

Irradiation Conditions: 51 kGy at -30°C

- The preferred irradiated sample was the one with 1% NaCl and 0.5% TPP

Table 23 - Effect of NaCl and TPP on the Sensory Characteristics of Non-Irradiated Pork Rolls

NaCl %	TPP %	Sensory Characteristics												Preference		
		Off- Odor			Salty Flavor			Off Flavor			Mushi- ness			Fria- bility		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
0.5	0.5	2.3	1.5	1.0	1.6	2.0	1.3	1.9	1.5	1.3	3.1	1.6	1.3	3.0	1.5	1.3
average*		1.6			1.6			1.6			2.0			1.9		
1.0	0.5	2.0	1.0	1.0	1.3	1.3	1.6	1.9	2.0	1.3	3.1	2.3	1.1	2.3	2.3	1.1
average*		1.3			1.4			1.7			2.2			1.9		
1.5	0.5	2.0	1.1	1.1	1.9	1.8	1.6	1.3	1.5	1.3	2.2	2.6	1.1	2.0	3.0	1.3
average*		1.4			1.8			1.4			2.0			2.1		
0.0	0.0	2.2	1.1	1.0	1.3	1.6	1.3	1.9	1.3	1.5	3.1	1.3	1.5	2.4	1.3	1.2
average*		1.4			1.4			1.6			2.0			1.6		

7 or 8 panelists per test, 9-point scale for preference

7-point reverse scale for sensory characteristics

*Mean of 3 tests in a 1 month storage period

- There was no preference for NaCl or TPP addition

Table 24 - Effect of NaCl and TPP on the Consumer Evaluation of Non-Irradiated Pork Rolls

<u>NaCl</u> <u>%</u>	<u>TPP</u> <u>%</u>	<u>Preference Scores</u> <u>Months of Storage</u>		
		<u>0</u>	<u>1</u>	<u>3</u>
0.00	0.0	6.2	5.7	5.2
0.50	0.5	7.0	7.2*	6.5
0.75	0.5	6.5	6.5	7.1*
1.00	0.5	7.2*	6.9	7.1*
1.50	0.5	6.7	6.7*	6.6

35 panelists per test, 9 - point scale

* significantly preferred to the sample with no NaCl or TPP

- Except for the sample with no additives, the preference scores held up well with storage. All the samples with additives were preferred over the one without additives.

Table 25 - Effect of NaCl and TPP and Storage Time on the Sensory Characteristics of Pork Rolls

NaCl %	TPP %	Storage Time months	Sensory Characteristics						Pref- erence
			Discolor- ation	Off Odor	Irrad. Flavor	Off Flavor	Mushi- ness	Fria- bility	
0.00	0.0	0	1.9	2.1	2.3	1.8	1.8	1.6	6.0
0.00	0.0	1	1.9	1.9	2.4	1.6	2.1	1.6	6.3
0.00	0.0	3	2.1	2.1	2.7	1.7	3.0	2.1	4.6
0.00	0.0	6	2.1	1.6	1.3	2.4	2.4	2.9	5.3
0.50	0.5	0	2.3	2.1	2.4	1.4	1.5	1.5	5.8
0.50	0.5	1	2.4	2.6	2.4	1.6	2.3	2.6	5.9
0.50	0.5	3	1.3	2.6	2.3	1.6	2.6	1.6	5.6
0.50	0.5	6	2.3	2.0	1.6	1.4	2.6	2.4	6.1
0.75	0.5	0	2.0	2.0	2.4	1.5	2.5	2.3	6.0
0.75	0.5	1	2.5	1.6	2.1	1.3	2.3	1.6	6.5
0.75	0.5	3	2.4	2.2	2.2	1.9	3.2	2.0	4.9
0.75	0.5	6	3.1	2.3	1.7	1.4	2.3	2.5	5.1
1.00	0.5	0	1.9	1.9	2.1	1.1	1.4	1.4	6.1
1.00	0.5	1	1.9	1.9	2.5	1.5	2.6	2.6	5.8
1.00	0.5	3	2.9	2.0	1.9	1.6	2.0	1.7	5.3
1.00	0.5	6	4.4	2.1	1.9	1.9	2.0	1.7	5.6
Nonirradiated		Control							
0.00	0.0	0*	--	--	--	--	--	--	--
0.00	0.0	1*	--	--	--	--	--	--	--
0.00	0.0	3	1.0	1.0	1.0	1.1	1.0	1.1	6.9
0.00	0.0	6	1.3	1.3	1.0	1.7	1.3	1.3	6.7

* Evaluations lost

7 - 8 panelists per test, 9-point preference scale,

7-point reverse scale for sensory characteristics

Irradiation Conditions: 51 - 66 kGy at -30 °C

- There was a decrease in ratings between 3 and 6 months of storage.
All the irradiated samples rated worse than the non-irradiated one.
There was no effect of additive addition.

Table 26 - Effect of NaCl and TPP on the Sensory Characteristics of Pork Chops

<u>NaCl</u>	<u>TPP</u>	<u>Irradiation Dose</u>	<u>Score after Days of Storage</u>	
<u>%</u>	<u>%</u>	<u>kGy</u>	<u>0</u>	<u>30</u>
<u>A. Preference</u>				
0.00	0.00	51	5.1	5.8
0.75	0.00	51	5.6**	6.2
0.75	0.25	51	6.3*	6.1**
0.75	0.50	51	6.3*	6.5
0.75	0.25	NA	7.1*	7.3*
<u>B. Texture</u>				
0.00	0.00	51	5.4*	5.5**
0.75	0.00	51	6.4	6.3
0.75	0.25	51	5.8	6.5
0.75	0.50	51	6.1	6.5
0.75	0.25	NA	7.1	7.3
<u>C. Flavor</u>				
0.00	0.00	51	4.8	5.7**
0.75	0.00	51	5.4	6.1
0.75	0.25	51	5.4	5.8**
0.75	0.50	51	5.5	6.7
0.75	0.25	NA	6.8***	7.6
<u>D. Odor</u>				
0.00	0.00	51	4.9	7.1****
0.75	0.00	51	5.9	6.6
0.75	0.25	51	6.4*	7.0
0.75	0.50	51	6.4*	6.9
0.75	0.25	NA	6.9*	7.7
<u>E. Color</u>				
0.00	0.00	51	5.7**	6.7
0.75	0.00	51	6.1	6.7
0.75	0.25	51	5.6**	6.9****
0.75	0.50	51	6.6	7.3
0.75	0.25	NA	6.9	7.5

10 to 12 panelists per test, 9-point scale

* significantly different from the sample with no additives

** significantly different from the non-irradiated control

*** significantly different from the irradiated samples

**** significance found between storage times

significance at 0.05 level

- All the irradiated samples rated worse than the non-irradiated.
There was no general additive effect.
There was a general increase in scores with increased storage.

Table 27 - Effect of NaCl and TPP on the Sensory Characteristics of Radappertized Pork Chops

<u>NaCl</u>	<u>TPP</u>	<u>Score after Days of Storage</u>	
<u>%</u>	<u>%</u>	<u>0</u>	<u>30</u>
<u>A. Preference</u>			
0.00	0.00	5.0	6.4**
0.75	0.00	5.1	6.2**
0.75	0.25	6.5*	6.8
0.75	0.50	6.2*	6.7
<u>B. Texture</u>			
0.00	0.00	6.0	6.5
0.75	0.00	6.1	6.0
0.75	0.25	6.6	7.3
0.75	0.50	6.2	6.9
<u>C. Flavor</u>			
0.00	0.00	4.4	6.2**
0.75	0.00	4.5	6.4**
0.75	0.25	6.0*	6.8
0.75	0.50	5.7*	6.8
<u>D. Odor</u>			
0.00	0.00	5.2	6.4**
0.75	0.00	5.3	7.2**
0.75	0.25	6.9*	7.2***
0.75	0.50	6.0	7.2***
<u>E. Color</u>			
0.00	0.00	6.1	7.4**
0.75	0.00	6.3	6.6
0.75	0.25	6.5	7.5**
0.75	0.50	6.2	7.2**

10 - 12 panelists per test, 9-point scale

* significantly different from the samples with no additives and 0.75% NaCl

** significance found between 0 and 30 days of storage

*** significantly different from the sample with no additives

significance at 0.05 level

- The addition of TPP increased the scores.
The scores increased with storage time.

Table 28 - Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Pork Products

<u>NaCl</u>	<u>TPP</u>		<u>Sensory Characteristics</u>											
<u>%</u>	<u>%</u>		<u>Color</u>		<u>Odor</u>		<u>Flavor</u>		<u>Texture</u>		<u>Appear- ance</u>		<u>Prefer- ence</u>	
<u>NaCl</u>	<u>TPP</u>	<u>Dose</u>	<u>Storage Time Days</u>											
<u>%</u>	<u>%</u>	<u>kGy</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>	<u>0</u>	<u>30</u>
<u>A. Rolls</u>														
0.00	0.00	51	5.7	5.6	5.6	3.8	5.2	5.5	5.4	5.0	5.7	5.3	5.7	5.2
0.75	0.00	51	6.9	5.7	5.2	5.4	5.4	5.6	5.7	5.3	5.6	5.9	5.3	5.7
0.75	0.25	51	4.8	6.3	4.8	6.1	4.7	5.9	5.8	6.3	5.0	6.1	5.2	6.1
0.75	0.50	51	5.6	6.2	5.5	6.5	5.5	6.1	5.6	5.7	5.8	6.4	5.7	6.2
0.75	0.25	NA	7.0	6.5	6.7	6.9	7.2	6.8	7.0	6.8	7.1	6.6	7.4	7.2
<u>B. Chops</u>														
0.00	0.00	51	5.7	6.9	4.9	7.1	4.8	5.7	5.4	5.5	6.3	6.6	5.1	5.8
0.75	0.00	51	5.8	6.8	5.9	6.6	5.4	6.1	6.4	6.3	6.4	6.8	5.6	6.2
0.75	0.25	51	5.6	7.4	6.4	7.0	6.5	5.8	6.3	6.5	6.1	7.0	6.2	6.1
0.75	0.50	51	6.6	7.3	6.4	6.9	5.5	6.7	6.1	6.5	7.1	7.5	6.2	6.3
0.75	0.25	NA	6.9	7.5	6.9	7.5	6.9	7.6	7.1	7.3	7.2	7.7	7.1	7.2

10 to 12 panelists per test, 9-point scale

Irradiation Conditions: 51 kGy at -25 ±20 °C

- There was no preference for the type of pork.
The storage time had no general effect.
The non-irradiated sample was preferred to all the irradiated samples.
There was no general effect of the additive addition.

Table 29 - Effect of NaCl, TPP and Storage Time on the Sensory Characteristics of Pork Products

NaCl	TPP	Irrad. Dose	Sensory Characteristics											
			Color		Odor		Flavor		Texture		Appear- ance		Pref- erence	
			Storage Time, Days											
%	%	kGy	0	30	0	30	0	30	0	30	0	30	0	30
A. Chops														
0.00	0.00	51	6.1	7.3	5.2	6.5	4.4	6.2	6.0	6.3	5.7	7.2	5.0	6.4
0.75	0.00	51	6.3	6.6	5.3	7.2	4.5	6.4	6.1	6.0	6.6	6.7	5.2	6.2
0.75	0.25	51	6.5	7.5	6.5	7.5	6.0	6.8	6.6	7.1	6.6	7.1	6.5	6.8
0.75	0.50	51	6.2	7.2	6.0	7.3	5.7	7.3	6.2	6.8	6.4	6.9	6.2	6.7
0.00	0.00	NA	7.2	7.4	6.4	7.0	5.7	6.9	5.6	6.3	7.1	7.1	5.9	6.9
0.75	0.00	NA	7.3	7.4	7.0	6.4	7.0	6.7	6.9	6.6	7.3	6.7	6.9	6.9
0.75	0.25	NA	7.4	7.0	7.4	6.4	7.2	6.7	7.3	6.6	7.3	6.7	7.1	6.9
0.75	0.50	NA	7.5	7.3	7.3	7.1	7.2	7.4	7.0	6.8	7.2	7.0	6.9	7.2
B. Rolls														
0.00	0.00	51	6.2	6.1	6.2	6.2	5.2	6.2	5.2	6.0	5.9	6.4	5.6	5.9
0.75	0.00	51	6.0	6.3	6.1	5.7	5.7	6.2	6.2	5.8	6.2	6.2	5.5	5.8
0.75	0.25	51	5.5	6.0	5.7	6.2	5.4	6.2	6.0	5.6	5.7	6.5	5.4	6.0
0.75	0.50	51	5.7	6.1	5.7	6.3	5.0	6.0	6.6	6.4	5.7	6.4	5.6	6.0
0.00	0.00	NA	6.0	7.1	5.9	6.7	5.7	7.0	5.2	6.9	5.7	7.0	5.9	6.8
0.75	0.00	NA	6.0	6.9	5.7	7.0	6.0	6.9	6.4	6.9	5.7	7.0	6.1	6.8
0.75	0.25	NA	5.7	6.9	6.1	6.2	6.2	6.7	6.5	6.7	5.5	6.7	6.0	6.5
0.75	0.50	NA	5.7	6.5	5.8	6.7	6.2	7.1	5.7	6.9	5.8	6.7	6.0	6.7

10 to 12 panelists per test, 9-point scale

Irradiation Conditions - 5.1 kGy at -25 ± 20 °C

- There was no preference for the type of pork.
The scores generally increased with storage time.
The non-irradiated samples had better scores than the irradiated samples.
There was no effect of additive addition.

This document reports research undertaken at the U.S. Army Soldier and Biological Chemical Command, Soldier Systems Center, and has been assigned No. NATICK/TR-99/009 in a series of reports approved for publication.